CONF-7910117--1

A MULTIDISCIPLINARY APPROACH TO RECLAMATION OF ABANDONED REFUSE SITES

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by

Stanley Zellmer and Michael Wilkey

MASTER

Prepared for

Coal Conference and Expo V

Louisville, Kentucky

October 23-25, 1979

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A MULTIDISCIPLINARY APPROACH TO RECLAMATION OF ABANDONED REFUSE SITES*

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Abstract

The Staunton 1 Reclamation Demonstration Project involves an evaluation of the reclamation process at an abandoned coal mine refuse site in southwestern Illinois. A multidisciplinary team of scientists and engineers selected the site, collected baseline environmental data, determined the final land use, and developed and implemented detailed engineering plans. Refuse material at the 34-acre site was recontoured and covered to a minimum depth of one foot with soil obtained on-site.

This same multidisciplinary approach is being used to evaluate post-construction environmental conditions at the site. Current investigations are monitoring conditions related to groundwater, surface water, aquatic ecosystems, revegetation, soils, erosion and runoff, soil microbial populations, and wildlife invasion. Information collected to date indicates that a significant improvement has occurred in the environmental quality of the site. The economic benefits of the effort are also being investigated and documented; a substantial increase in the economic potential of the site and adjacent properties has been recorded. The project is demonstrating methods that can be used to reclaim abandoned coal refuse sites and is providing design data for future reclamation efforts of this type.

Introduction

Until recent enactment of state and federal coal refuse disposal laws, the methods and sites for disposing of refuse materials from coal preparation plants were usually determined by convenience and economic consideration. Little or no thought was given to the long-term environmental consequences of such indiscriminate actions. Coarse refuse (gob), usually dumped near the preparation plant, often created large, steep-sided piles. Effluent (slurry) from the coal washers was pumped into a nearby impoundment where solids were allowed to settle out. While present-day mines are required by law to use disposal methods and sites that minimize environmental damage, many abandoned (pre-regulation era) refuse sites remain today as serious ecological, economic, and aesthetic problems.

When pyritic material, often associated with coal refuse, is exposed to the atmosphere, oxidation and hydrolization occur and strong acids are formed. Acidic runoff from the refuse site degrades surface water quality and causes deterioration of the aquatic environment. Acidic water with high concentrations of sulfate and metal ions may contaminate the local groundwater system. The refuse material becomes acidic and creates adverse conditions for plant establishment and growth. Without a protective vegetative cover, the refuse material is easily eroded and the resulting sediment is carried onto adjacent areas. This cycle continues as erosion exposes more unweathered pyritic material. Conceivably, hundreds of years could be required for reclamation of a coal refuse site by natural processes, during which time the environment would continue to be adversely affected.

Abandoned mine-refuse areas, i.e., those where no one has reclamation responsibilities, in an unreclaimed condition have no real land use and only limited economic value. Often these sites become unauthorized dumps which create public health hazards. Generally, refuse areas are unsightly, and the addition of discarded materials detracts even more from their appearance. These conditions, together with the meager environmental status of such sites, create a depressed economic market for adjacent properties.

The area occupied by abandoned coal refuse sites is sizable; in Indiana, for example, unreclaimed coal refuse sites occupy approximately 3200 acres (4), and in Illinois, it is estimated that there are over 9000 acres of abandoned exposed coal refuse (8). From a regional standpoint, coal refuse sites represent a significant land area; the U.S. Bureau of Mines estimates that almost 125,000 acres of land were used in Appalachia between 1930 and 1971 for the disposal of deep mine refuse materials (10).

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*This project was financially supported by the following agencies: U.S. Department of Energy, Contract No. W-31-109-Eng-38; Illinois Abandoned Mined Land Reclamation Council (Capital Development Board Project No. 555-090-004); Illinois Institute of Natural Resources, Project No. 80.043.

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The U.S. Department of Energy, through the Land Reclamation Program* at Argonne National Laboratory, and two Illinois agencies -- the Abandoned Mined Land Reclamation Council and the Institute of Natural Resources -- have developed a cooperative project to address the problems associated with reclaiming a refuse-disposal site at an abandoned deep mine. A major objective of this project is to develop, demonstrate, and evaluate methods for reclaiming abandoned coal refuse sites in order to provide the greatest benefits at the lowest costs. The collection and documentation of detailed information on the various aspects of the reclamation process is providing design data for federal and state agencies and the coal industry. Additional objectives of the project are common to all reclamation efforts. They are to: a) reduce the quantity of pollutants entering the environment, b) increase the economic potential of the area, and c) improve the aesthetic value of the locality.

The project has been subdivided into the following phases:

Phase I	Planning and Design
Phase II	Baseline Monitoring
Phase III	Site Development
Phase IV	Postconstruction Evaluation

Because no one technical discipline encompasses the full spectrum of knowledge required in the reclamation process, a multidisciplinary team was used to design and evaluate the entire reclamation effort. Each phase of the project involved interactions between individuals with various skills and technical training. In the planning and design phase of the project, recommendations of the scientific staff were incorporated by the engineering staff into a design compatible with the proposed land use. Environmental and physical data collected by scientists during baseline monitoring were utilized by engineers in the final design. The expertise of the construction industry was utilized during site development. Incorporated into the project design and construction were facilities to evaluate the effectiveness of various reclamation techniques.

Phase I - Planning and Design

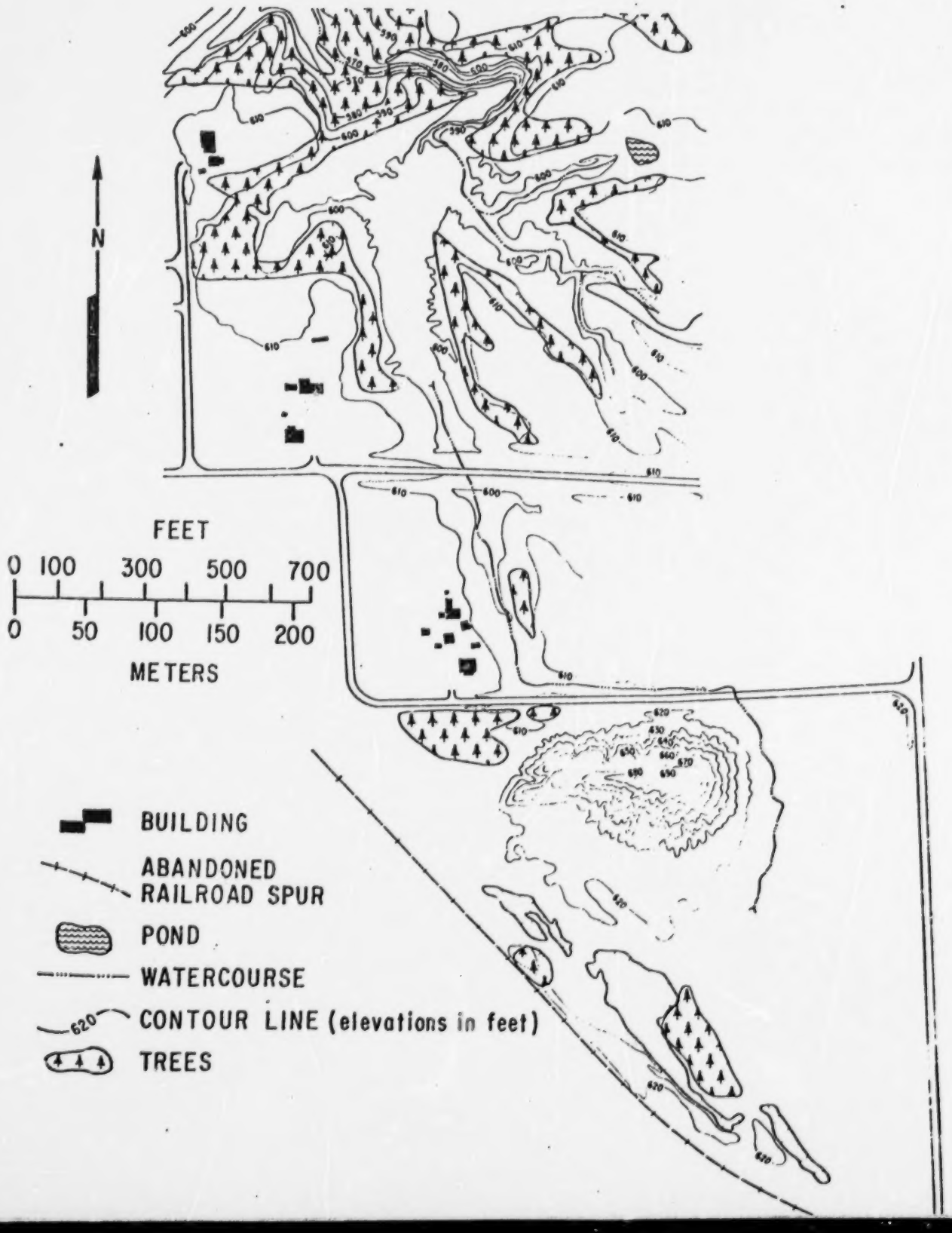
The planning and design phase of the project started in late 1975 with the selection of a typical deep coal mine refuse area, the old Consolidated Coal Company's Mine No. 14, located near Staunton, Illinois, in Macoupin County. The mine was opened in 1904 and operated for approximately 19 years, mining the Herrin (No. 6) coal through a 275-ft-deep vertical shaft. The coal was dry, non-gaseous, and contained about 5% sulfur. Like other mines of the area, Consolidated No. 14 was noted for its good roof, and subsidence was not a problem. Double-entry room and pillar extraction was used, with the coal loaded by hand underground. An average work force of 500 men extracted 5000 tons of coal per day during maximum production.

The total site (Figure 1) included 34 acres, of which about 23 acres had been affected by the past mining operation and required reclamation. Dramatic evidence of the mining and coal-cleaning operation existed in the form of a gob pile, a steep-sided refuse heap that rose about 80 ft above the natural landscape and covered almost 5 acres. In the 50-odd years the mine had been closed, erosion had cut deep gullies into the face of the gob pile; no vegetation had become established on the gob or in adjacent areas affected by the acid runoff and sediment. A 175-ft-high concrete smokestack, a remnant of the mine's power plant, was still standing, but only the foundations of other mine structures remained. The rails from a siding which served the mine had been removed, but the right-of-way was still evident along the southern boundary of the property. The gob pile and the site of the old cleaning plant, tipple, and rail yard occupied about one-third of the total property.

Before the mine was opened, a dam had been built across a deep ravine near the site's north boundary. The 11-acre impoundment created by the dam provided water for the mine's power plant and coal-cleaning operation, and also served as a sump for the slurry produced by the coal cleaning. All drainage from the site was into this impoundment, and after the mine was closed, the area continued to fill with sediment from the gob pile. This refuse material reached a maximum depth of 30 ft and, due to its acidic nature, prevented vegetation from becoming established. In the early 1940's the dam was breached, resulting in erosion of the old slurry area and gullies as deep as 15 ft. Acidic runoff and sediment were carried down a small stream about one-half mile to Cahokia Creek.

*The Land Reclamation Program is a joint effort of the Energy and Environmental Systems Division and the Environmental Impact Studies Division at Argonne National Laboratory.

Fig. 1. Staunton 1 Reclamation Demonstration Site
Before the Site Development Phase.



The site had been used as a general dump for many years and was littered with trash and debris. There was evidence that small game used the remaining one-third of the site covered with volunteer shrubs, grasses, and trees. It was also evident that the site had been used by off-road vehicles and as a target range by hunters.

The second task in this phase of the project was to determine the final land use of the site. Because the area is near a railroad, improved roads, and a small industrial area, a possible usage would have been as an extension of the industrial development, which would have complemented the City of Staunton's economic base. After a soil investigation of the site, however, this land use was determined to be impractical. Since one of the goals of reclamation is the mitigation of pollution, the acidic runoff from the refuse material had to be controlled and a vegetative cover was essential to control erosion and reduce runoff. The project staff held discussions with local officials and regional planners, and further investigation determined that the community had a need for additional recreational areas. With these considerations in mind, a final land use was selected as a combined recreational area, wildlife habitat, and ecological education area.

With this final land use in mind, development began on detailed engineering plans and specifications. In general, the reclamation plan included: recontouring of refuse materials, disposal of man-made structures, improvement of the water courses, development of a pond, and reconstruction of the old dam and addition of water flow-control structures. Following recontouring, a neutralizing agent would be incorporated in the surface of the refuse material. Exposed refuse material would then be covered to a minimum depth of 1 ft with suitable cover material (soil) obtained on site. Preparation of a seedbed would include liming and fertilizing, and the site would be seeded with a mixture of grasses and legumes.

Phase II - Baseline Monitoring

Concurrently with the planning and design phase of the project, a baseline monitoring phase was instituted to assess the site's preconstruction environmental and physical conditions. This phase provided data for the development of detailed design plans and is now providing a means to measure the effectiveness of the reclamation effort.

A number of observation wells were installed to establish and determine the groundwater quality of the site. Groundwater in the glacial till underlying and adjacent to the gob pile had low pH and high concentrations of sulfate, alkaline earths, and heavy metals. These leachate constituents were not found in groundwater samples collected from wells at distances greater than 300 ft from the gob pile. Groundwater samples collected from wells in the saturated slurry material also had low pH and high concentrations of sulfate, alkaline earths, and heavy metals. Samples from residential wells of the area were found to contain primarily calcium, magnesium, carbonates, and sulfates, but appeared to be unaffected by the refuse site (12). Surface water collections were made at the site starting in the spring of 1976. In general, surface water pH was very low, and had high concentrations of sulfate, iron, zinc, and cadmium (see Table 3).

Surface samples were collected and routine soil analyses were made to determine the availability of various plant nutrients and the suitability of the surface materials for vegetation establishment and growth. All samples were generally low in pH and in available plant nutrients. Both gob and slurry were high in soluble salts and had excessive amounts of boron and zinc, which may have interfered with vegetative growth. The bulk density of both the gob and slurry material was low (< 1.00) and showed a general lack of large-size particles (> 1 in.); this may have been due to either the method of mining or of coal cleaning.

Other monitoring activities on the site included sampling and analysis of surface materials for soil microbes. The gob and slurry areas lacked most forms of soil microbial life normally found under cultivated agricultural conditions (6). However, soils from adjacent fields did contain those forms of soil microbes. A limited wildlife inventory was also made of the site; areas not affected by the refuse material had wildlife populations normally found in the area, but those populations made little use of the refuse area itself. Extensive growth-chamber studies were conducted at ANL to investigate the effects of various types and levels of soil amendments, as well as to determine which vegetative species which could best be used in reclaiming the site (3). Results of these studies were used in selecting soil amendment types and rates, and species to be seeded on the site.

Phase III - Site Development

In the late summer of 1976, the Illinois Abandoned Mined Land Reclamation Council purchased the site and awarded the construction contract to a Springfield, Illinois, firm. The Council contracted to have the staff of the Land Reclamation Program act as resident engineers for the project during the site development phase.

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Site development began immediately with the removal of the smokestack and mine structure foundations, and the disposal of accumulated debris. The borrow pit was opened, and cover material removed and stockpiled. Within six weeks, grading had reduced the gob pile to approximately one-third of its original height. During grading of the slurry area, the contractor experienced problems in moving equipment over the saturated slurry material. Application of a neutralizing/stabilizing agent, and the arrival of colder weather that caused the ground to freeze, aided in the recontouring of the slurry area. As construction progressed, the Staunton area experienced its severest winter on record. Due to the extreme weather conditions, all construction activities stopped for two weeks in February.

Grading of the site was completed after construction activities resumed, and the application of neutralizing materials at the refuse/cover-material interface began. The neutralizing agents were applied at a rate of 78 tons $CaCO_3$ equivalent per acre, and incorporated to a minimum depth of 6 in. into the recontoured refuse materials using an industrial disk harrow. Cover material from the borrow pit was then placed on the recontoured refuse material in a 1-ft-thick layer. An application of 5 tons/acre of agricultural limestone, and 120 lbs/acre each of nitrogen, phosphorus, and potassium plant nutrients was made to the recontoured area. These amendments were disked to a minimum depth of 4 in. during seedbed preparation. The area was then planted, using an agricultural grain drill, with the seed mixture listed in Table 1. Species for the seed mixture were chosen for their tolerance to acidic and infertile conditions. The cereal rye was added as a nurse crop to provide a quick ground cover. Seeding, fencing of the site perimeter, and final cleanup were completed by the end of April, 1977. Construction statistics are listed in Table 2.

Table 1. Seeding Mixture Applied to the Site, Spring 1977

Species	lbs/ac
Reed canarygrass (Phalaris arundinacea L.)	10
Tall fescue (Festuca arundinacea Schreb.)	15
Birdsfoot trefoil (Lotus corniculatus L.)	12
Ladino clover (Trifolium repens L.)	5
Cereal rye (Secale cereale L.)	20

Phase IV - Postconstruction Evaluation

The end of the site development phase (Figure 2) coincided with the beginning of the postconstruction evaluation phase, which employs a number of interrelated research projects. Each subproject is examining a specific portion of the reclamation effort and the combination of findings from each individual subproject is providing an overall assessment of reclamation effort at the site. Because reclamation involves many factors and interactions, each individual subproject must be viewed as a part of the whole and not necessarily an end in itself. Postconstruction evaluation activities are also providing means to investigate and study possible remedies of potential environmental problems that develop on the site. Investigations are involved with groundwater, surface water quality, aquatic ecosystems, revegetation, soil characteristics, erosion and runoff, soil microbial and wildlife populations, and economic benefits of the reclamation effort.

A postconstruction groundwater investigation (13) was initiated at the site with the installation of 47 shallow (6 ft to 40 ft) observation wells. Twenty-six of the wells provide water samples from below the refuse material, while the remaining 21 wells are in the refuse itself. An additional 15 nearby residential wells, ranging in depth from 15 ft to 40 ft, are included in the study. Because groundwater flow is relatively slow compared to surface runoff, the long-term effects of site development on groundwater quality are expected to be subtle. To date, however, the project has had no affect on the quality of water in local residential wells. Groundwater quality has improved greatly in the area of the old slurry pond, but has remained poor in the area of the recontoured gob pile.

Surface water quality was one of the major environmental problems at the site before the effort started (9). A program of surface water sampling and analysis has been underway since the project began. Results from representative sampling periods of surface water leaving the site are shown in Table 3.

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Fig. 2. Staunton 1 Reclamation Demonstration Site
After the Site Development Phase

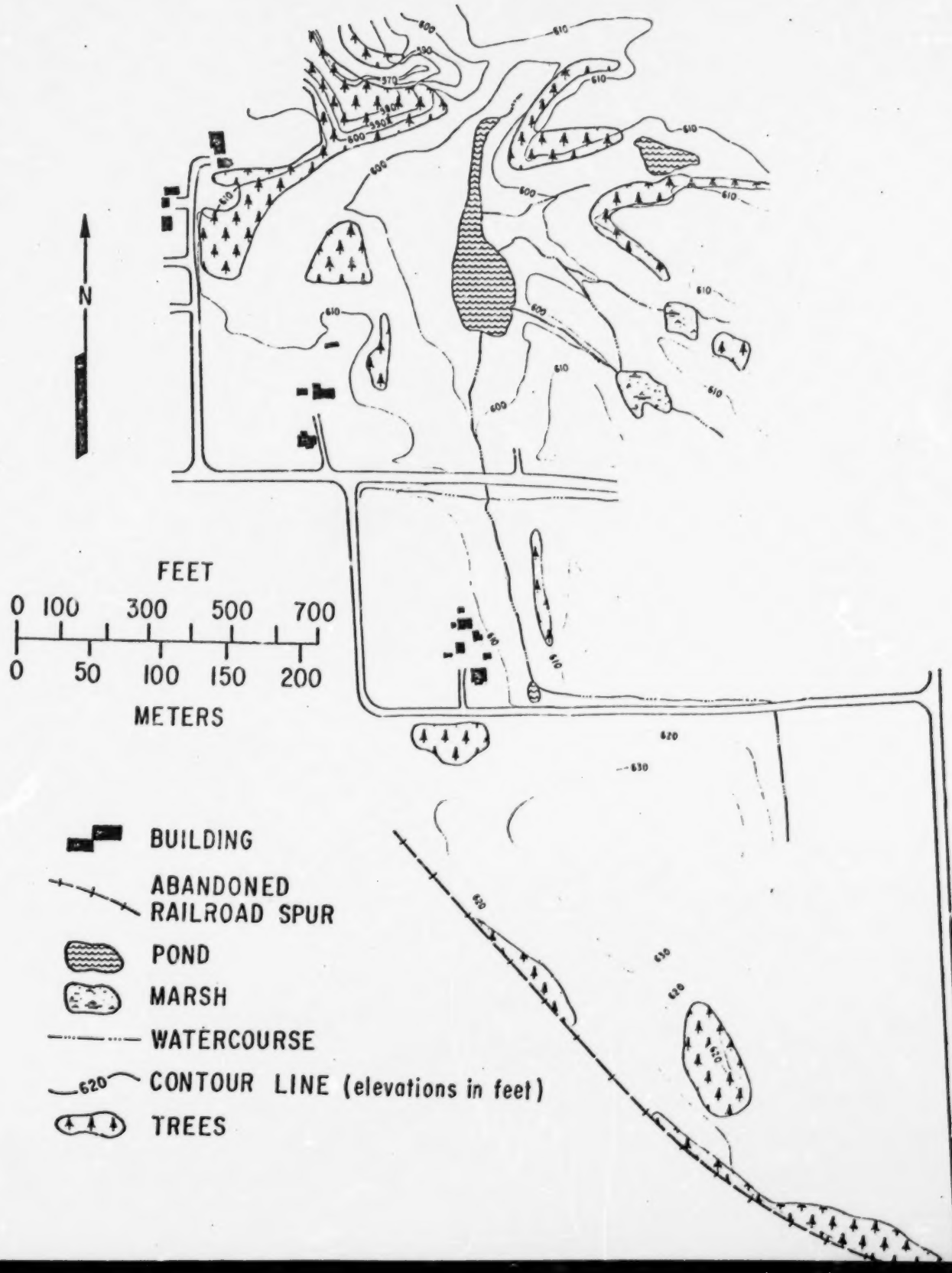

Table 2. Construction Quantities and Costs for the Staunton 1 Reclamation Demonstration Project

Description	Quantity Completed	Unit of Measure	Unit Price Dollars	Amount Paid
Engineer's Field Office, Type B	1	Each	1,200.00	$ 1,200.00
Tree Removal	4	Acres	1,100.00	$ 4,400.00
Borrow Excavation	39,545	Cu Yd	3.10	$122,589.50
Pipe Culvert, Type 4a	226	Lin Ft	40.00	$ 9,040.00
Class X Concrete	10	Cu Yd	500.00	$ 5,000.00
Refuse Relocation	236,473	Cu Yd	1.57	$371,262.61
Removal of Smokestack	1	Each	4,800.00	$ 4,800.00
Agricultural Ground Limestone	834.6	Ton	12.00	$ 10,015.20
Code L Alkali	681.6	Ton	17.14	$ 11,683.14
Nitrogen Fertilizer Nutrient	2,430	Pounds	1.10	$ 2,673.00
Phosphorus Fertilizer Nutrient	2,430	Pounds	1.10	$ 2,673.00
Potassium Fertilizer Nutrient	2,430	Pounds	1.00	$ 2,430.00
Special Seeding	20.2	Acres	700.00	$ 14,140.00
Culvert Relocation	1	Each	3,000.00	$ 3,000.00
Sediment Retainers	6	Each	250.00	$ 1,500.00
Fencing	7,350	Lin Ft	1.29	$ 9,500.00
TOTAL				$575,906.45

NOTE: Completed quantities are rounded to nearest 0.1 unit of measure. Unit prices are rounded to nearest cent.

Table 3. Water Quality of Surface Water Samples During Various Phases of the Project

	Preconstruction	Construction	Postconstruction			
Parameter[a]	4/14/76	3/18/77	5/11/77	8/16/77	5/9/77	8/9/78
pH	3.9	3.8	4.1	8.4	4.5	6.4
Alkalinity	0.0	0.0	0.0	38.0	0	13
Acidity	3596	393	288	0.0	84	17
Sulfate	7095	1850	1200	500	200	780
Iron	1450	119	0.71	0.08	1.56	0.33
Zinc	75.0	26.7	11.3	0.02	3.03	0.09
Cadmium	0.59	0.44	0.20	<0.01	<0.02	<0.01

[a]All units except pH are in mg/L.

The flow rate of water leaving the site is being monitored, and evaluation of the data indicates that peak flows of surface runoff from the site have been greatly reduced. This decreased runoff from the recontoured site is presumably due to increased infiltration as a result of the decreased slope angles and the success of revegetation. Normal storage capacity of the retention pond serves to reduce peak flows during major precipitation events.

Chemical quality of water seeping from the base of the recontoured gob pile is poor (e.g., pH less than 4 and high levels of acidity, sulfate, iron, manganese, and toxic metals). While the flow rate of this seepage is low, a substantial amount reaches the retention pond and apparently affects water quality in the pond. The effect appears to be most pronounced during the winter when good quality surface runoff into the pond is minimal. Despite the slight deterioration of on-site surface waters, effluent leaving the site continued to be far superior to preconstruction conditions, and it is highly unlikely that the postconstruction effluent has had an adverse affect on the water quality and aquatic biota of Cahokia Creek.

Certain macroinvertebrates in the aquatic ecosystem (14) are known to be sensitive indicators of surface water quality and can give long-term indications of water quality conditions, whereas water samples only give the conditions present at the time of collection. Macroinvertebrate sampling is done at regular intervals in the on-site ponds and in Cahokia Creek, which drains the site. Preconstruction assessments of the Cahokia Creek macroinvertebrate communities indicates that populations were low. Data from the creek samples indicate the impacts from the site drainage are probably too subtle to be factored from the overriding influence of other unreclaimed refuse sites within the watershed.

Benthic macroinvertebrates were sampled from two on-site ponds -- an established pond unaffected by the past mining operation, and the new pond created as part of the site development. Comparisons of the ponds allowed interpretations to be made concerning the development of the new pond as a potentially productive aquatic ecosystem. The benthos of the new pond was dominated by Diptera (true flies) larvae. Some species of dragonflies, damselflies, mayflies, and beetles were also present in low numbers. Most collected species were either very tolerant of conditions associated with acid mine drainage, e.g., Chironomus plumosus, or at least not indicative of pristine environments. The new pond is an apparent benefit to the wildlife in the site vicinity. However, water quality conditions of the new pond, as indicated by the benthic macroinvertebrates, do not warrant fish stocking in the pond at present.

The site-wide revegetation success study (5) is using a point-intercept method to monitor vegetative cover on an individual species basis and to determine the effect of various microclimates on revegetation success. Five study plots were established and vegetative cover data has been collected on each study plot for two growing seasons. Based on the standard of 70% to 80% vegetative cover used by numerous state and federal agencies, revegetation of this site can be considered successful. The amount of vegetation established on the site and proportion of vegetative cover contributed by seeded species is increasing. However, slopes of the recontoured gob pile are subject to water erosion and loss of the cover soil. The higher soil temperatures and lower soil moistures observed on the south-facing slope of the pile have inhibited nurse crop establishment, thus allowing substantial losses of cover soil. The heavy stands of invading species on this south-facing slope in the summer following seeding probably inhibited establishment of subsequent seeded species. Plant establishment on the north-facing slope was adequate for protection of most of the cover soil from erosion.

Standing water and sediment accumulation in the wide drainageways of the site were thought to have adversely affected establishment of seeded species. However, dense stands of vegetation composed of seeding and invading species became established in these areas. Of the five seeded species included in the seed mixture, birdsfoot trefoil and tall fescue provide the greatest plant cover on the average. Ladino clover did poorly overall on the reclaimed site.

The second revegetation study (2) is determining cost-effective means of achieving long-term vegetation success on amended refuse material. Replicated plots were constructed for each of eight treatments. Combinations of four cover depths (0, 6 in., 12 in., and 24 in.) and two liming rates (50 tons/acre and 100 tons/acre) at the refuse/cover material interface are being evaluated. A mixture of seven grass species and one legume was planted on all plots. Germination, plant density, vegetative cover, and biomass are determined for each treatment. Exposed refuse was ineffective in establishing any plant species.

During the initial growing season (1977), invader species constituted 82% to 99% of the average total plant production per replicated plot. Plant biomass data, collected one year later, indicate a complete reversal of species composition, with planted species making up 98% to 68% of the total biomass. During the first growing season, seed production by invaders, specifically foxtail, was quite high. Qualitative observation during the second growing season indicated that the foxtail seed germinated and seedlings formed a dense mat under the planted perennials, but never developed to reproductive maturity.

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Revegetation studies are finding that high soil temperature and low available soil moisture on some parts of the site have inhibited plant establishment, which in turn allowed substantial erosion of cover soil. Data indicate that birdsfoot trefoil and blackwell switchgrass were the most successful species planted in the revegetation research plots after two growing seasons, but rooting depths on areas with 1 ft or less of cover soil may be insufficient during periods of drought.

Data on soils from the site have been collected in order to determine if significant changes occur, over a period of time, in the physical and chemical characteristics of the root zone material. A partial listing of the results from the chemical analysis of a representative soil sample is given in Table 4. The heavy application of neutralizing material at the 12 in. to 18 in. level is very evident. These data and observations of root penetration indicate that favorable chemical conditions exist for plant root establishment at the 12 in. to 18 in. depth.

Table 4. Chemical Analysis of a Representative Soil Sample Collected on the Site in June 1977

Depth in.	pH	Exchangeable Calcium ppm	Exchangeable Magnesium ppm	Extractable Zinc ppm	Electrical Conductance mmhos/cm	Neutralization Potential[a]
0-6	7.7	3700	560	0.3	4.0	142
6-12	7.4	10400	480	2.7	3.5	198
12-18	5.4	16100	260	14.0	2.8	13
18-24	2.4	3700	120	92.0	13.6	-22

[a]Tons $CaCO_3$/1000 tons material.

The principal factors of rainfall, soil properties, slope, and vegetative cover in the soil-loss equation affect the quality and quantity of surface runoff water. Incorporated into site development plans were three study slopes with horizontal-to-vertical ratios of 3:1, 5:1, and 7:1. On each of these slopes, plots with three depths of cover material (0, 6 in., and 12 in.) were constructed. Replicated erosion/sedimentation monitoring devices were installed on the plots. Data (Table 5) indicate that major differences exist in runoff water quality and quantity between the plots where cover material was applied and those where refuse was left exposed.

Runoff volumes were also higher on slopes with no cover material. However, this may be due to the general lack of vegetation on these slopes during the first year. Additional data suggest, as would be expected, that runoff quantity increases as the slope angle increases. The data gathered from this research, when coupled with cost factors from each slope and cover depth, will determine the economic and environmental feasibility of each treatment.

Table 5. Surface Runoff Water Quality and Percent Runoff of a 1.8 in. Rainfall on a 3:1 Slope

Cover Depth (in.)	pH	Zinc mg/L	Iron mg/L	Acidity[a] mg/L	Sulfate mg/L	Percent Runoff
0	3.3	8.9	103.2	837.5	1454	43.0
6	5.9	1.2	1.3	30.15	179	24.2
12	5.8	0.4	0.5	8.04	56	22.3

[a]$CaCO_3$ equivalent.

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Soil microbial populations (7) are an integral part of the below-ground ecosystem and of communities involved with the transformation and availability of plants nutrients. The microbial community, following site development, have achieved numbers equal to adjacent old-field soils, but diversity of the system, as measured by species numbers, is much lower. Cellulose and grass litter decomposition rates are determined for old-field soils and the revegetation research plots. Plot decomposition rates were similar, but none achieved rates equal to the old-field soil. The half-life for litter is approximately 82 days for old-field soils, 433 days to 577 days for plots with suitable cover material, and 533 days for plots with amended, exposed gob. All information indicates that a functioning saprophytic community has been reestablished. Changes in soil microbial population, i.e., bacteria, actinomycetes, and fungi, are also being used as a measure of success. All measurements indicate that these organisms have gained a foothold at the site.

At the Staunton 1 site, one of the planned land uses is that of wildlife habitat. Wildlife inventories (11) are made periodically to document the invasion and establishment of wildlife species at the site. Small mammals are monitored by live trapping and other species are documented through direct observations or by signs (tracks, scat, burrows). Bird surveys are conducted along established transect lines on the site and in the old-field and forest-edge communities adjacent to the site.

Nine mammal species have been observed on the site. Species captured by live-trapping are the prairie vole, meadow vole, house mouse, and Norway rat. Larger mammals observed on site were cottontails, raccoon, opossum, muskrat, and deer. Eighteen bird species have been noted on-site. Common amphibians observed in the pond include the American toad, southern leopard frog, and Blanchard's cricket frog. Reptiles, including the six-lined racerunner, blue racer, black rat snake, and box turtle, are frequently observed on-site and in adjacent areas. Wildlife species observed are typical of early old field-communities in southwestern Illinois.

Economic benefits (1) of a reclamation effort can be made by comparing pre-reclamation property values, tax assessments, or economic growth of the area with post-reclamation values. Although the site is not totally reclaimed, i.e., the planned land use for the site as a recreation area has not been met, many economic benefits have accrued. An appraisal of the site was made in April 1976 before construction activities started, and a second appraisal was made approximately one year after the end of the site development phase (May 1978). These appraisals indicate an increase in the site's value of about 530%.

Increase in land values for surrounding property have been estimated by averaging Staunton realtors' estimates and changes in tax assessments. Surrounding land values have increased by 70% to 100%. Tax revenues from adjacent properties to the township are expected to double, in some cases. Economic growth of the area is indicated by the construction of a new home near the site; the owner has stated that his $60,000 house would not have been built if the reclamation effort had not taken place. These activities are assumed to reflect improvements in aesthetics, health, and safety, and to provide urban development opportunity in the area.

Other economic benefits of the project included employment during site development, reduction of damage from acid drainage, and improvements in construction techniques resulting from the specialized knowledge gained by the site development contractor.

Regional economic benefits and improvements in construction efficiency benefits resulting from the project are in the range of $340,000 to $430,000 over the next 50 years. This provides a benefit/cost ratio of 0.48/1 to 0.60/1. This analysis cannot reflect the entire purpose of this project, although it goes far toward answering concerns about improving the economic potential of the area and reducing future construction costs.

Summary

The Staunton 1 Reclamation Demonstration Project is designed to provide data on many aspects of the reclamation process. Information collected to date indicates that a significant improvement has been made in the overall environmental quality of the site, and that there is a reduction in the quantity of acid mine drainage, heavy metals, sediment, and other pollutants entering the environment. Data from the economic benefits portion of the project suggest a substantial increase in the economic potential of the site and adjacent properties. The reactions of visitors and local residents to the site implies a genuine enhancement of the entire area's aesthetic value.

During the course of this project, a multidisciplinary team of engineers and scientists interacted during all phases of the reclamation effort. The expertise for reclaiming lands affected by coal mining is not the domain of any one technical discipline. A multidisciplinary team approach is required for the successful implementation of future reclamation efforts. The Staunton 1 Reclamation Demonstration Project, while serving to reclaim this site, is also providing a much broader benefit by furnishing the necessary design data for future reclamation efforts of this type.

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